



2026 White Paper

PV Plant Decommissioning and Repowering Case Study

Robert O. Schulz Solar Farm, South San Joaquin Irrigation District



TABLE OF CONTENTS

- Abstract [2](#)
- Introduction..... [2](#)
- Solar Farm Overview..... [3](#)
- Mid-Life Challenges..... [4](#)
- Repowering Planning [6](#)
- PV2 Redevelopment..... [8](#)
- PV1 Redevelopment..... [9](#)
- Equipment Disposition and
Site Restoration.....[11](#)
- Redevelopment Benefits
and Costs[11](#)
- Decommissioning Cost
Comparisons[14](#)
- Cost Modeling Tool
Calibration[17](#)
- Conclusions.....[18](#)
- Acknowledgments[20](#)
- References[20](#)

Photo Credit (cover and above):
South San Joaquin Irrigation District

ABSTRACT

Deployed in 2008-09 as an early large-scale solar power project, the Robert O. Schulz Solar Farm incorporated crystalline silicon and cadmium telluride module technologies on tracking arrays. After a decade of high-value operation for South San Joaquin Irrigation District, failing inverters, aging-related performance degradation, and other factors caused significant reductions in net-metered energy production and cost savings. This case study reviews asset management and repowering planning processes and phased implementation of a partial decommissioning and redevelopment project involving replacement and disposition of legacy technologies and reuse of existing equipment. A flexible, shared-risk approach to contracting based on engineering-level field assessments helped ensure that the repowering was completed on schedule, within budget, and without significant production losses. Generating capacity increased by 46% within the same physical footprint, and simple payback is expected in less than 2 years. Documented experiences can help owners and operators of legacy or underperforming solar plants in assessing mid-life challenges and constraints, evaluating asset management options, and developing and implementing decommissioning plans, creative equipment reuse and project redevelopment strategies, and phased repowering plans.

INTRODUCTION

The number and the total capacity of operational large-scale photovoltaic (PV) power plants continue to grow. Prior to construction, project developers or asset owners often are required to provide landowners and jurisdictional authorities with documentation estimating the costs of future decommissioning and ensuring that adequate funds will be available for facility removal and site restoration at end of life or in the event of default or abandonment. Over expected multi-decade lifetimes, operational facilities will age and decline in productivity while newer, higher-yield technologies enter the market, leaving owners to decide how to manage individual assets, whether by maintaining them to optimize performance, revamping or redeveloping them by replacing originally installed technologies, or fully decommissioning them and restoring sites for future land uses.

Experience with PV plant repowering and decommissioning is expanding globally as the incentive programs, power purchase agreements, and land leases that enabled early deployments approach or reach their expiration dates. Previous EPRI reviews of publicly available literature indicate significant uncertainty regarding the disposition and value of used modules, a high degree of variability in site-specific decommissioning cost estimates and repowering work scopes, and limited availability of real-world cost data [1,2].

Decision methods and modeling tools are necessary to evaluate the financial, power generation, and other implications of alternative asset management scenarios throughout the lifecycle of operational PV plants, especially those that are underperforming, approaching or at the end of warranty protections, or nearing the end of contractual commitments or economic viability. Cost-and-material

estimates for decommissioning and repowering conceptual PV plant designs are required to support the development of effective modeling frameworks. Real-world data for repowered and decommissioned PV systems can then be used to validate and/or calibrate models.

The PV RESOLVE (Reliable Entire-System Operations and Lifecycle Value Evaluation) project, led by the U.S. Department of Energy's National Laboratory of the Rockies (NLR) and including EPRI as a partner, aims to provide owners, financiers, operators, and purchasers with a consistent framework for evaluating the implications of a variety of asset management scenarios—at any life stage of a large-scale solar system—to support decision-making for continued operation, repowering, or retirement. This includes development of a cost modeling tool that will enable users to input information about their specific system as well as key assumptions, to calculate costs for given scenarios, and to examine sensitivities to factors such as the resale value of used modules, the cost of recycling end-of-life modules, the salvage value of recovered materials, and the scope of repowering and site restoration.

An important step in cost modeling tool development is calibration against current industry costs and experiences. This white paper presents a case study analysis of the partial decommissioning and redevelopment of an early solar farm owned and operated by the South San Joaquin Irrigation District (SSJID) in central California. Beyond presenting cost data, the case study shares details collected through interviews with SSJID personnel and contractors and through reviews of internal documents to illuminate the iterative nature of solar asset management, the impacts of myriad factors on real-world outcomes, and lessons learned.



Figure 1. Two silicon-based tracking arrays (PV1) were installed in 2008, followed by 2009 deployment of a thin-film array (PV2) in the vacant lot at left. (Credit: SSJID)

In addition, case study data are compared to data collected from other sources, including another solar farm decommissioning completed in 2025, a number of decommissioning plan cost estimates prepared in 2024-25, and recent and ongoing EPRI work. As a publicly available resource, this paper provides useful insights into the emerging practice of solar plant repowering and decommissioning and highlights the need for consistent and comprehensive cost modeling.

SOLAR FARM OVERVIEW

SSJID's Robert O. Schulz Solar Farm supplies net-metered power to reduce the cost of operating the neighboring Nick C. Groot Water Treatment Plant, which began serving the cities of Manteca, Tracy, and Lathrop in 2005. The generating facility, installed in two phases by project developer Conergy Americas, represented an early large-scale deployment of state-of-the-art PV module and tracking technologies. At commissioning in 2008, the plant included a 1.176-MW_{DC} single-axis tracking array (PV1) incorporating two blocks of 175-watt (W) Conergy monocrystalline silicon (c-Si) modules served by five 250-kilowatt (kW) Xantrex central inverters (Figure 1). In 2009, a 0.4176-MW_{DC} array (PV2) of 72.5-W First Solar cadmium telluride (CdTe) modules was added in conjunction with two 250-kW Xantrex inverters, becoming the first commercial-scale thin-film tracking system in the United States [3]. Module mounting and support systems were fabricated from industrial-grade, corrosion-resistant structural steel members, leading to an "Excellence in Hot-Dip Galvanizing" award from the American Galvanizers Association [4]. Tracker array steel piles, inverters, and other components were affixed to concrete slabs.

Total installed costs were about \$11.7 million for overall generating capacity of 1.594 MW_{DC} and net inverter capacity of 1.392 MW_{AC}. SSJID deployed the side-by-side arrays to compare the two different module technologies and incorporated 1.75 MW_{AC} of total inverter capacity with a plan to eventually double the size of the PV2 array based on the developer's expectation that CdTe would outperform c-Si under site-specific cloud, haze, and dust conditions. Annual savings on electricity costs for the water treatment plant were projected to be in the range of \$400,000, with PV output to be purchased at a 15% discount relative to utility rates [5]. In addition, SSJID anticipated receiving energy revenue, based on the difference between the treatment

plant’s purchase price and the value of net energy metering (NEM) credits under the NEM1 program administered by California Public Utilities Commission (CPUC).

While PV2 was not expanded, the solar farm—incorporating technologies new to the U.S. market at the time—provided consistent production across its first decade as shown in Figure 2, at a net AC capacity factor of about 25%. On average, about 70% of the treatment plant’s electricity needs were met during the six sunniest months and about 25% for the remainder of the year. Based on annual net energy revenues exceeding \$300,000 and \$6.4 million in state-level production incentives, the project was on a path toward simple payback of installation costs in the 2023-24 timeframe. In addition, hundreds of thousands of dollars in annual treatment plant operating cost savings had been passed on to water consumers [6]. Despite these direct and indirect benefits, SSJID was facing decisions on the project’s continued operations in the years ahead.

MID-LIFE CHALLENGES [7]

At inception, the anticipated solar farm lifetime was 20 years, with the first 10 years covered under an operations and maintenance (O&M) agreement with Conergy Americas. As a subsidiary of c-Si module manufacturer Conergy,

which filed for insolvency in 2013, Conergy Americas was sold off, and successor entities provided declining levels of service. In 2018, field workers at SSJID’s neighboring water treatment facility were assigned O&M responsibility by default, despite lacking experience or training. Performance and reliability issues began to mount, driven by aging and failing PV system equipment.

Figure 2 shows that year-over-year production steadily declined from 2017-2019 and plummeted by 43% in 2020. With a new time-of-use (TOU) tariff from host utility Pacific Gas & Electric (PG&E) going into effect, SSJID began 2021 facing a substantial reduction in both the quantity and value of net-metered output. In response, asset management services provider TerraVerde Energy was hired to assess the condition of the solar plant from both performance and safety perspectives based on reviews of maintenance records, production and billing data, and photos of fielded components and systems. Around the same time, SSJID negotiated an updated interconnection agreement with PG&E under CPUC’s NEM2 program, superseding two separate NEM1 agreements for PV1 and PV2. The agreement, still scheduled to expire in 2028, treats the solar farm as a single net-metered generating facility exceeding 1 MW.

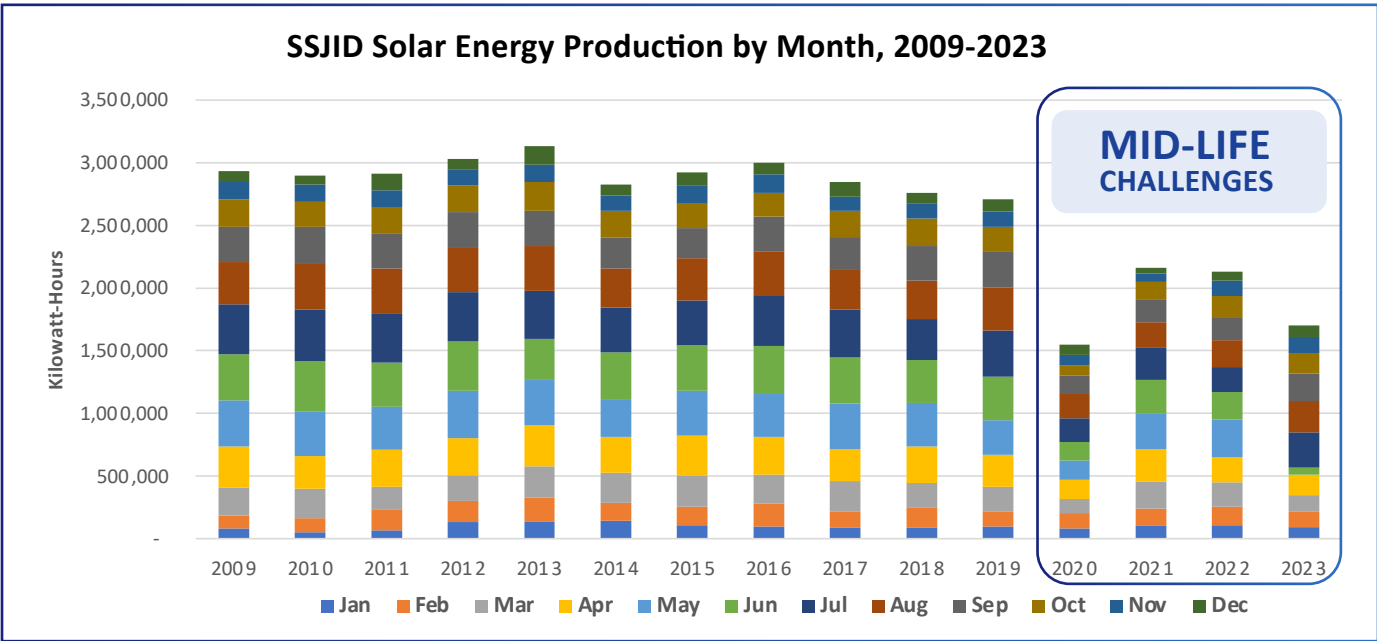


Figure 2. Annual and monthly solar energy data illustrate consistent annual output—and high productivity during summer months—through 2016, followed by a downward trend and then a dramatic mid-life decline.



Figure 3. After a productive first decade, the solar farm's degraded performance created needs for more proactive asset management. (Credit: SSJID)

Comparing actual 2020 production to weather-adjusted expected output, TerraVerde reported monthly performance ratios ranging from 45 to 75% and an annual average of 55% [8]. By contrast, according to NLR's PVFleet analyses, modern and well-maintained utility-scale PV plants offer annual performance ratios of about 75 to 85%, declining to an average of around 70% for legacy plants impacted by operational issues and degradation of fielded modules [9]. At the SSJID facility, the main causes of underperformance and lost production were inoperable and failing inverters; aging-related degradation, extensive soiling, and failure of modules; inadequate management of DC wiring; and periodic failure of trackers. Safety concerns included loose wiring and connections, scorch marks within combiner boxes, and potential for module hot spots due to cracking, delamination, and moisture ingress. Based on desktop assessment and the lack of recent documented work by an experienced solar O&M provider, TerraVerde Energy was authorized to conduct a field inspection and plant recommissioning.

Visual and thermal inspection identified 26 damaged modules impacting string-level production, while mechanical and electrical testing featured detailed evaluation of inverters, wiring, monitoring systems, structural supports, AC transformers, and tracker drives and controls, with the

latter engaging SSJID water treatment facility personnel, who had periodically been maintaining and replacing motors and other components. In addition to panel cleaning, recommissioning tasks included tightening and replacement of module mounting brackets and connectors, installation of new wiring fasteners and DC module leads where required, and sealing around exposed conduit connections. Damaged modules were left in place due to the absence of spares. While AC disconnect switches were replaced on two inoperable PV1 inverters, one unit could not be restarted. DC wiring was reconfigured to connect the stranded block of capacity with operational inverters.

Collectively, these 2021 interventions addressed safety concerns and increased output to about 80% of the anticipated level, accounting for aging-related performance degradation and observed weather conditions [10]. However, the persistent availability losses and reliability concerns attributable to failing and failed components—combined with less favorable utility rates—lowered annual net energy revenues by about 55% relative to the historical average. In addition, PV2 was determined to be on the brink of system-wide failure based on the condition of its legacy CdTe modules and inverters.

In Fall 2022, SSJID's newly hired electric utility manager collaborated with local PV engineering consultants to evaluate three asset management options:

- **Run to retirement:** Allow the degraded project to safely sunset toward decommissioning as originally scheduled in 2028, with minimal maintenance investment.
- **Revamp:** Restore production by conducting "light maintenance," featuring inverter refurbishment and array reconfiguration based on reuse of operable parts and components.
- **Redevelop:** Increase capacity and extend lifetime by investing in "enhanced maintenance," featuring phased replacement of end-of-life inverters and the degraded PV2 array.

The SSJID Board of Directors authorized "enhanced maintenance" in November 2022, agreeing to invest \$1 million over a 2-year period based on a detailed cost-benefit analysis accounting for estimated increases in production and updated TOU rates. At the time, expectations were that equipment replacement would allow at least a decade

of reliable operation for the redeveloped solar farm, that annual cost savings realized by water consumers would continue to accumulate, and that new PV modules would translate to additional annual net energy revenue of about \$100,000, resulting in simple payback in about 10 years. SSJID's electric utility manager was directed to pursue cost-effective implementation, as well as explore additional possibilities for optimizing the value of the solar plant.

REPOWERING PLANNING [11]

In assessing redevelopment options, the SSJID team faced two key constraints. Drop-in replacements for central inverters with maximum operating voltage of 600 volts (V) are not available in today's marketplace, and legacy modules and wiring are incompatible with modern 1000-V plant architectures incorporating string inverters. Other planning considerations included taking advantage of today's higher-capacity module technologies, avoiding the need to renegotiate the interconnection agreement, maximizing reuse of balance-of-plant systems, and reducing downtime and production losses during repowering implementation.

The 2020 cancellation of a PV project at the City of Manteca's wastewater treatment plant ended up playing a critical role in the repowering planning process. The equipment for the 3.34-MW_{DC} array had already been procured—at an estimated cost exceeding \$3 million—when city officials decided to explore alternative uses for the proposed installation's site. In early 2023, SSJID approached city officials, who agreed to sell, at a heavily discounted price, 8912 JA Solar 375-W c-Si modules, 40 SunGrow 60-kW string inverters, and other components that had been shipped and placed in storage 2 years prior.

With assurance that warranty and other protections were transferable, in May 2023 the SSJID Board authorized a purchase price of \$1.25 million based on energy and economic analyses indicating that replacing failed modules and all of the inverters and wiring across both PV1 and PV2 would increase production by 25 to 35% initially and support at least 20 years of integrated solar farm and water treatment facility operation. This more aggressive redevelopment plan was projected to boost net energy revenues by about \$350,000 annually and allow the district to continue to deliver hundreds of thousands of dollars in annual cost



Figure 4. Replacement of legacy technology and reuse of industrial-grade support structures were foundational elements of the repowering plan. (Credit: SSJID)

savings for Manteca and other water consumers. The net present value of the total authorized investment of \$2.25 million was estimated to be about \$7 million, with simple payback in about 7 years.

The SSJID team initiated preliminary engineering based on the specifications of the replacement equipment. While available modules and inverters represented enough to double the generating capacity of a redeveloped array, the NEM2 agreement only allowed for an increase of up to 10% from the inverter nameplate of 1.75 MW_{AC}, imposing an upper limit of 1.925 MW_{AC}. SSJID's goals of maintaining the plant's existing physical footprint and reusing underground conduit, AC transformers, and mounting rail, tracking, and support hardware—combined with needs to accommodate higher-capacity modules having 40% to 240% more surface area than legacy panels—set additional design constraints.

In Summer 2023, SSJID issued a request for proposals (RFP) for repowering engineering services for redevelopment of the existing solar farm to increase capacity by up to 10%, with implementation to be performed in phases to minimize lost production [12]. The baseline work scope encompassed repowering options analysis, cost estimation, and development of construction plans, specifications, and schedules for removal and disposition of end-of-life inverters and modules and reuse of existing array hardware (Figure 4) to support installation of replacement equipment already procured from Manteca. Alternative proposals, such as adding more generating capacity or developing a new community solar project using equipment not needed during the repowering, were encouraged.

The RFP scope did not include construction and other field services, which at the time were expected to be performed by SSJID and/or outside contractors. No as-built drawings or documentation of underground infrastructure were available. The SSJID team hosted a site visit, addressed questions from interested parties, and provided data addressing solar energy production, treatment facility electricity demand and use, and utility bills and tariffs. Seven formal proposals were received—some fully responsive to the RFP’s baseline scope—and several creative ideas were submitted, as were pitches to “rip and replace” the existing solar farm with all-new equipment. Based on comparative evaluation, including customized net present value analyses, the three highest-ranked respondents were invited for interviews.

Ultimately, a repowering services provider was selected based on relevant expertise, recent experience with a similar repowering project, readiness to start work immediately, and willingness to collaborate with SSJID in optimizing the decommissioning and construction sequence and implementing a shared-risk phasing strategy. In addition, two opportunities illuminated during the competitive bidding process were carried forward for possible future implementation: (1) reduction in net repowering investment by meeting eligibility requirements for renewable energy deployment incentives newly available to tax-exempt entities like SSJID under the Inflation Reduction Act (IRA) of 2022; and (2) value creation by deploying an on-site battery energy storage system (BESS).

In early 2024, the SSJID team expanded to include the electric utility manager and PV engineering consultants; Mel Bradley Consulting, responsible for on-site design assistance; Jolt Engineering, charged with preparing construction plans; and NuLife Power Services, responsible for repowering engineering and construction at an estimated total not-to-exceed cost of \$3 million, with phasing to occur through approval of individual task orders (Figure 5). NuLife’s scope included execution planning, sequencing strategy, and coordination of decommissioning and repowering tasks—including removal and disposition of legacy equipment, installation of previously procured components, and commissioning of redeveloped strings—to minimize downtime and production loss across both the PV1 and PV2 arrays.



Figure 5. SSJID’s repowering contractor provided engineering and construction services and coordinated all field activities. (Credit: NuLife Power Services)

The team’s first step was to finalize the redevelopment sequence and design. Lacking as-built drawings, NuLife began by conducting rigorous field evaluations to guide execution planning and sequencing, enable accurate cost development, and inform engineering. The assessments addressed condition, code compliance, compatibility with new equipment, and warranty risk for all components, including tracker frames and hardware, structural supports, grounding systems, underground trench and conduit runs, pull boxes and conduit systems, PV switchboards, AC transformers, revenue meters, and utility AC disconnects.

Technical analyses and recommendations directly shaped the project scope, phased work plan, and budget, including final reuse, upgrade, and replacement decisions and engineering plans developed in coordination with the project team. For example, all grounding components including ground bushings, lugs, array grounding straps, and grounding conductors were designated for replacement to ensure safety, code compliance, and long-term system integrity. Custom engineering was required to develop new array layouts, integrate string inverters, and reuse underground conduit and central inverter pads to avoid the need for trenching and foundation work.

PV2 REDEVELOPMENT [13]

PV2 was prioritized as the lowest-performing array with the simplest redevelopment path forward—and the potential to resume operation, at increased capacity, during summer months with the highest solar output and value. PV1 repowering was delayed to Fall 2024 to minimize the impact of production losses and allow time for work scope optimization. The repowered PV2 design reuses the original tracker array frames and support structures based on engineering analyses indicating that attaching new modules with a larger surface area to existing galvanized steel beams would require modified universal fastening object hardware but no new bracing, and that components carrying fewer

lighter modules would experience reduced structural and wind loading relative to the original plant design.

NuLife initiated field work in February 2024 under time-and-materials task orders limited to PV2 and \$950,000. The company also assumed responsibility for managing all field requirements, including collaboration with local labor organizations to meet prevailing wage, workforce classification, and apprenticeship standards consistent with IRA eligibility requirements, as well as for developing and implementing environmental, health, and safety programs. Site-wide safety protocols and emergency response procedures governed all parties, and work was coordinated around live tracker movement in close collaboration with SSJID personnel, whose ongoing involvement was essential to keeping portions of the system operational throughout construction.

After construction mobilization, decommissioning tasks involved de-energizing inverters, disconnecting DC wires and cables, and removing cables from conduit, as well as careful removal and handling of 5760 spent CdTe modules to avoid breakage. Inverters were also removed for temporary on-site storage while awaiting a disposition decision. Per instructions provided by First Solar, which had included the cost of transportation and recycling in SSJID's original purchase price for the modules, serial numbers were recorded, and junction boxes were detached using an industrial-grade scraper (Figure 6). Intact modules were stacked two-by-two, front-to-back, on 48 x 48 inch single-stringer pallets, with no more than 76 modules per pallet, and then strapped down for pickup and transport by First Solar. Junction boxes, DC wires and cables, and other ex-service components were stockpiled for later salvage.

PV2 includes 24 rows of modules in landscape orientation with a central tracker. Tracker array frames, each 122 inches tall by 1212 inches long, had been built to accommodate thin-film modules measuring 24.3 x 48 inches, while the replacement c-Si modules are 39 x 72.2 inches. For each of the 48 frames, three rows of 15 new modules (16.875 kW_{DC}) were installed to replace five rows of 24 legacy modules (8.7 kW_{DC}). During module removal and installation, some trackers were inadvertently overextended, shearing pins. For the remainder of the repowering, water treatment facility staff assumed responsibility for properly positioning



Figure 6. CdTe modules were processed according to First Solar's instructions, and tracking array frames were reused with a new module layout. (Credit: SSJID)

Table 1. Comparison of Original and Redeveloped PV2 Array

Specifications	PV2 Original	PV2 Redeveloped
Number & Type of Modules	5760 thin-fim CdTe	2160 c-Si
Module Rating	72.5 W	375 W
Gross DC Capacity	0.4176 MW	0.81 MW
Number & Type of Inverters	2 central inverters	12 string inverters
Inverter Rating	250 kW	60 kW
AC Capacity	0.5 MW	0.72 MW, derated to 0.66 MW

trackers to avoid damage during module replacement. In total, 2160 modern modules were affixed to the existing frames, almost doubling PV2’s gross generating capacity to 0.81 MW_{DC} as shown in Table 1.

Prior to deployment of new DC wiring and communications cable, underground conduits were thoroughly inspected and mandrel-tested to verify they were clear, free of debris or water intrusion, and suitable for reuse. Twelve strings were created, each connecting modules from two rows, and the cable pull from the arrays to the inverter pad went smoothly as PV2 conduit had been oversized in 2009 to accommodate additional capacity that ultimately was not built. The 12 string inverters, each connected to 180 modules and derated to 55 kW apiece for a total of 0.66 MW_{AC}, were deployed on new racking installed in the area of the pad formerly occupied by central inverters. The racking incorporated two new AC combiner boxes—each accepting outputs from six inverters—serving a new PV switchboard with AC disconnects [14]. The original 750-kVA AC transformer, which had also been oversized when installed, was sufficient to accommodate the increased output.



Figure 7. For PV1, spot-welded bolts complicated removal and replacement of legacy c-Si modules. (Credit: SSJID)

PV1 REDEVELOPMENT [15]

On June 5, 2024, the redeveloped PV2 array began supplying electricity—and cost savings and revenue—both earlier than anticipated and under budget. To leverage previously approved funds and avoid demobilization and remobilization costs, the SSJID team decided to immediately move forward with a limited-scope pilot designed to inform the PV1 repowering strategy and reduce cost uncertainty and risk by providing guidance for addressing implementation challenges and potential physical constraints:

- Bolts affixing modules to array frames were tack-welded to protect against theft, creating potential for higher removal costs as well as equipment damage (Figure 7).
- Conduit runs to the centralized inverter pad were not oversized during construction.
- The PV1-North block supplies a 500-kVA AC transformer, sized based on 24 rows of legacy modules on paired arrays with a central tracker.
- The PV1-South block supplies a 750-kVA AC transformer, sized based on 32 rows of legacy modules on paired arrays with a central tracker.

To avoid production losses during summer when TOU rates are highest, the pilot was limited to the 12 PV1-North rows that had previously been supplying the inoperable central inverter. Under a \$175,000 task order, the preliminary plan was to remove modules from the pilot area for reinstallation as like-for-like replacements of damaged modules throughout PV1-North and PV1-South and to refurbish, maintain, and/or replace PV1’s inverters by scavenging parts from and/or refurbishing the inverters removed from PV2. However, mechanical removal of modules affixed by tack-welded bolts required both the industrial-grade

Table 2. Comparison of Original and Redeveloped PV1 Array

Specifications	PV1 Original	PV1 Redeveloped
Number & Type of Modules	6720 c-Si	4032 c-Si
Module Rating	175 W	375 W
Gross DC Capacity	1.176 MW	1.512 MW
Number & Type of Inverters	5 central inverters	24 string inverters
Inverter Rating	250 kW	60 kW
AC Capacity	1.25 MW	1.44 MW, derated to 1.167 MW

scraper and additional physical effort, in some cases resulting in breakage of cover glass and bent aluminum frames. While tracker frames were undamaged, c-Si modules were deemed to have no reuse value based on both physical and market conditions.

As a result, the plan to revamp PV1 with existing equipment was abandoned, and the focus shifted to redevelopment with new components. Modules, DC wiring, and cables removed from the 12-row pilot area were stockpiled, and underground conduit inspection and testing were conducted. Each 128 inches tall by 937 inches long, PV1 tracker frames had been designed for c-Si panels measuring 32 x 62.25 inches. Individual repowered arrays feature three rows of 12 modern modules (13.5 kW_{DC}) replacing four rows of 15 legacy ones (10.5 kW_{DC}). As of September 13, 2024, the pilot was operational with new wiring and cable running through underground conduit to three string inverters deployed on new racking on the centralized equipment pad, as implemented for PV2. In addition, redevelopment of the remaining 36 PV1-North tracker arrays was under way through a \$668,000 task order.

Stripped of legacy equipment and with new modules, wiring, cabling, and grounding, the remainder of PV1-North began operation on October 30, 2024. Across 1728 modules and 0.648 MW_{DC}, the repowered block includes a total of 10 inverters, with eight each supplied by 180 modules and derated to 52 kW, and two each supplied by 144 modules and derated to 42 kW, for a total of 500 kW_{AC} [16]. Derating inverters allowed the SSJID team to fill existing tracker arrays with new modules while staying within limits set by the capacity of the existing AC transformer and NEM2 agreement.

Leveraging PV2 and PV1-North designs, processes, and learnings, PV1-South redevelopment started in November 2024 with a production-driven goal of completing work by the end of winter. An initial \$700,000 task order resulted in 24 repowered rows beginning operation on January 22, 2025. A final \$384,000 task order included repowering of the remaining eight rows, site restoration for the entire work area, and a \$100,000 allowance for third-party recycling and disposal of stockpiled c-Si modules, other equipment, and waste materials. In addition, NuLife was responsible for creating a comprehensive O&M manual for the redeveloped solar farm, for working with SSJID and PV monitoring services provider AlsoEnergy to configure newly installed field equipment and an online dashboard, and for assisting SSJID in upgrading on-site security systems to prevent theft and vandalism. Jolt Engineering prepared final as-built drawings.

On March 26, 2025, repowered PV1-South commenced operation with 2304 new modules and generating capacity of 0.864 MW_{DC}. The design includes a total of 14 string inverters with combined net capacity of 0.667 MW_{AC}, with 10 string inverters, each supplied by 180 modules, derated to 52 kW; three units, supplied by 144 modules each, derated to 42 kW; and one inverter, supplied by 72 modules, de-rated to 21 kW [17]. As indicated in Table 2, redeveloped PV1 includes a total of 4032 modules and 1.512 MW_{DC} replacing 6720 modules and 1.176 MW_{DC} within the same footprint. The shared central equipment pad hosts 24 string inverters—with total net capacity of 1.167 MW_{AC}—feeding two new AC combiner boxes and the existing PV switchboard, disconnect switches, and AC transformers.

EQUIPMENT DISPOSITION AND SITE RESTORATION

Under regulations promulgated by the California Department of Toxic Substances Control (DTSC), PV modules deployed within the state are designated as waste once removed from service unless destined for reuse, and end-of-life modules are categorized as universal waste and must be transported and managed as hazardous unless designated otherwise. Disposal in conventional landfills is not an option. Damaged modules not intentionally broken or crushed are also eligible for universal waste designation. End-of-life modules are regulated as universal waste so long as they remain within the state's borders. Modules transported out of state are subject to applicable federal, state, and local regulations [18].

At the SSJID solar farm, intact CdTe modules were packaged for inspection, pickup, and out-of-state transport and recycling by the original equipment manufacturer at its facility in Ohio. First Solar recovers more than 90% of module glass and semiconductor materials, with the former sold for use in other products and Cd and Te supplied to a specialty refiner for purification and reuse in new thin-film modules [19].

Intact c-Si modules were stacked on and strapped to pallets and wrapped for shipping, and broken modules were secured in a container (Figure 8). A certified out-of-state recycler transported the modules to its processing facility in Nevada for materials recovery. Junction boxes were not removed, and no toxicity testing was performed prior to shipping, as DTSC regulations give waste generators and handlers the option of voluntarily designating ex-service modules as universal waste or of making a hazardous waste determination based on toxicity testing results or other available information. At the Nevada facility, modules were shredded, aluminum was recovered, and the mixture of glass, semiconductor, metal, and polymer was fed to a smelting line to recover copper, silver, and lead, leaving a residual suitable for use in cement making [20].

Both operable and inoperable Xantrex central inverters were sold to a local PV O&M services provider for use at other projects. Most other balance-of-plant components were left in place. Removed CdTe module junction boxes, wires and cables, and other waste materials with recovery value were stockpiled in containers for transport to a local



Figure 8. Legacy c-Si modules were stockpiled for transport and processing by an out-of-state recycling services provider. (Credit: SSJID)

salvage yard. Solid waste generated during decommissioning and repowering activities was collected in a dumpster for landfill disposal.

Site restoration requirements were minimal because the project substrate is unvegetated hardpan, and decommissioning and redevelopment tasks occurred within the same footprint and without excavation. Light grading was necessary to fill minor ruts that had been created by construction vehicles after rainfall, restore the hardpan surface, and ensure proper drainage. Approximately 50 cubic yards of gravel were applied to reinforce service vehicle pathways.

REDEVELOPMENT BENEFITS AND COSTS [21]

The repowered solar farm's total generating capacity is 2.322 MW_{DC} incorporating 6192 modules, and net inverter capacity is 1.827 MW_{AC} incorporating 36 string inverters. This represents a 46% increase in gross DC capacity and 31% increase in net AC capacity within the same physical footprint. Partial decommissioning and repowering were completed with zero lost-time injuries across the full scope of work, a notable safety outcome given the complexity of executing a live-system repowering with multiple phases. Redevelopment costs totaled about \$4.1 million, with this amount reflecting direct and indirect costs incurred by

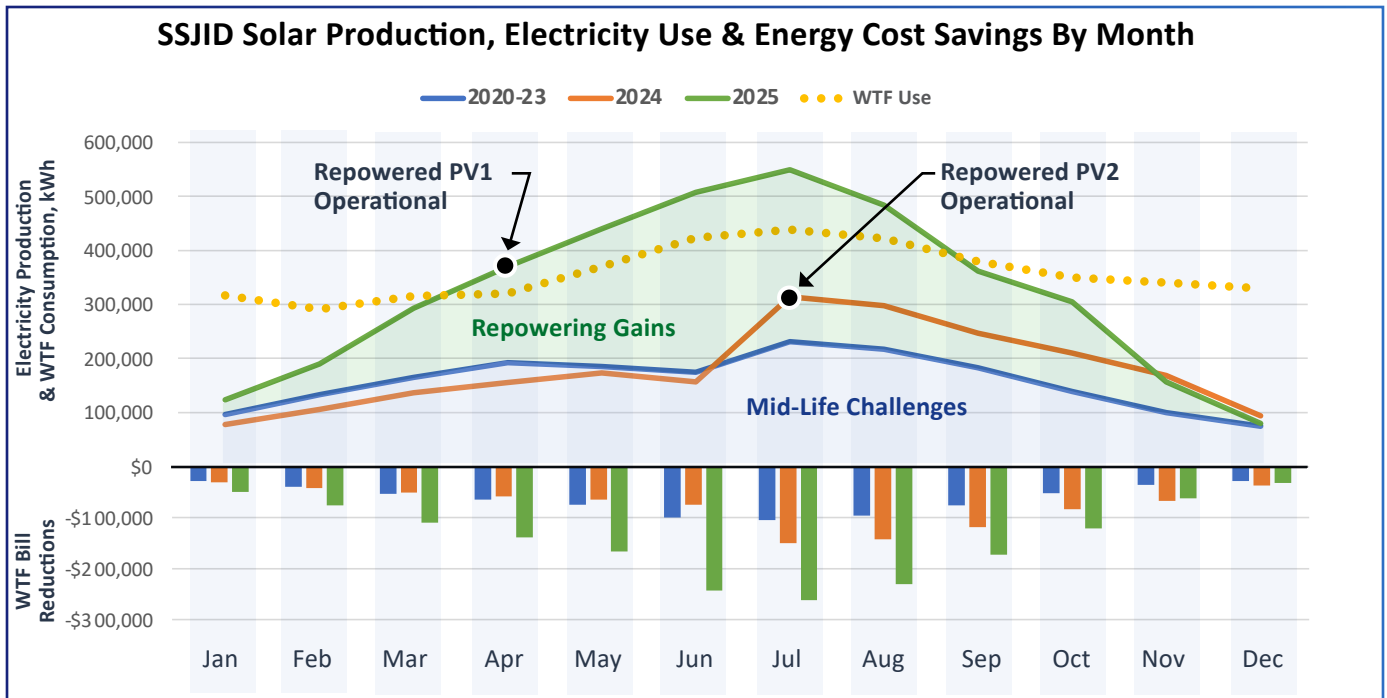


Figure 9. Phased repowering generated immediate and substantial increases in monthly solar energy production and cost savings for SSJID, helping drive a rapid payback.

NuLife, other contractors, third-party providers, and SSJID, including a pro-rated portion of the total cost of purchasing equipment from the City of Manteca. IRA direct payment incentives are expected to yield about \$1.2 million for eligible 2024-25 repowering expenditures.

Figure 9 compares average monthly generation for the underperforming SSJID project from 2020-23 to monthly output throughout and after the 2024-25 partial decommissioning and repowering sequence. It also illustrates monthly 2025 electricity use and solar energy cost savings for the neighboring water treatment facility (WTF), highlighting the value of phased intervention. Output and savings increased markedly in July 2024 once PV2 repowering was complete. After redeveloped PV1 was commissioned in March 2025, on-site generation exceeded on-site consumption across the high-use, high-cost summer months, helping drive annual savings on electricity costs of about \$1.65 million.

Accounting for much higher electricity cost savings and generous IRA incentives, simple payback on redevelopment investments is expected within 2 years—by the end of 2026. The remaining four string inverters and 2720 modules have been reserved for future PV plant operations, both as

spares and to allow for a possible expansion in generating capacity in conjunction with the potential development of an on-site BESS facility when the NEM2 agreement expires. SSJID’s capital plan for 2027-28 includes \$4 million to support BESS deployment, contingent on CPUC’s NEM3 provisions, updates to applicable tariffs, and continued cost-benefit analyses.

As shown on the next page, Table 3 summarizes decommissioning, repowering, and overall redevelopment costs, and Table 4 provides a breakdown of decommissioning costs by task and type of expenditure. About 81% of gross expenditures were for repowering, with the remainder for decommissioning. Procurement of new modules, inverters, DC and AC system hardware, and ancillary components—including shipping and storage expenses—was the single largest line item, at almost 35% of gross costs. Demolition and installation tasks together accounted for 46%, broken down into 85% for field labor, 7% for construction equipment, and 5% for materials. Indirects—including construction bonding, NuLife’s project management services, and SSJID’s internal engineering and management services and subcontracted providers—combined for about 16% of gross costs.

Table 3. SSJID Solar Farm Redevelopment Costs and Cost Metrics

Task Area	NuLife	SSJID	Total
Decommissioning Gross Cost			\$776,256
Demolition	\$495,420		\$495,420
Recycling & Disposal	\$107,293		\$107,293
Civil Works	\$8,889		\$8,889
Indirects	\$95,616	\$69,038	\$164,654
Gross, Per Module Removed			\$62
Gross, Per kW Removed			\$487/kW _{DC} ; \$558/kW _{AC}
Decommissioning Net Cost			\$726,126
Scrap & Salvage	-\$50,130		-\$50,130
Net, Per Module Removed			\$58
Net, Per kW Removed			\$456/kW _{DC} ; \$522/kW _{AC}
Repowering Gross Cost			\$3,352,170
Procurement	\$435,000	\$1,007,076	\$1,442,076
Installation	\$1,416,135		\$1,416,135
Indirects	\$286,847	\$207,112	\$493,959
Overall Redevelopment Cost			Gross: \$4,128,426; Net: \$4,078,296
Gross, Per kW Installed			\$1778/kW _{DC} ; \$2260/kW _{AC}
Net, Per kW Installed			\$1756/kW _{DC} ; \$2232/kW _{AC}

Table 4. SSJID Solar Farm Decommissioning: Cost Breakdown by Task and Type of Expenditure

Category	Labor	Materials	Equipment	Other	Subcontract
Demolition	\$426,154	\$23,375	\$33,173	\$12,718	
Recycling & Disposal					\$107,293
Civil Works		\$2889	\$6000		
Indirects	\$153,336			\$11,318	
Subtotals	\$579,490	\$26,264	\$39,173	\$24,036	\$107,293
Gross Cost Share	74.7%	3.4%	5%	3.1%	13.8%

Nearly 12% of decommissioning costs were spent on transportation and recycling of about 6700 c-Si modules. This included shipping 13 containers out of state for \$41,600 and processing at a cost of \$0.20/pound, corresponding to rates of \$13/module with shipping and \$7/module for recycling only. According to an EPRI survey of U.S. recycling service providers, the 2025 pricing range was about \$10-\$17/module, with some of these rates including transportation [22]. Credits against gross costs, shown as negative numbers and highlighted in red in the table, reflect positive cash flows from selling legacy inverters and from scrap and salvage revenues.

Overall redevelopment costs were in the range of \$1750-\$1780/kW of newly installed DC capacity and \$2230-\$2260/kW of derated AC capacity, considerably higher than median 2023 pricing data analyzed by NLR for new 1- to 5-MW PV projects in California [23]. However, partial decommissioning of existing arrays, custom engineering supporting creative reuse of structural systems, and retrofit installation of new equipment procured at a discounted price cannot reasonably be compared to developing a greenfield site. SSJID’s site-specific work scope combined with the lack of publicly available cost data make comparisons with other PV plant redevelopment projects challenging.

DECOMMISSIONING COST COMPARISONS

During preparation of this case study, service provider Decom Solar supplied EPRI with a current cost estimate prepared to support the 2025 decommissioning of another early utility-scale plant incorporating CdTe modules—a

3.821-MW_{DC}/3.0-MW_{AC} facility deployed in 2009 on a U.S. Air Force base in Tucson, Arizona. At an estimated gross cost of almost \$1.4 million, the decommissioning scope involved removal of the fixed-tilt solar field, balance-of-plant equipment, and ancillary facilities to the point of interconnection, including 45,000 modules, six 500-kW inverters, DC and AC systems, support structures, and a tie-line and substation. The solar plant was de-energized and removed due to the expiration of its 15-year power purchase agreement and its degraded condition, as legacy modules had reached the end of their useful operational life. As with the SSJID project, CdTe modules were picked up and recycled by First Solar at no cost, having been included as a bundled service in the module purchase price. After the fact, Decom Solar verified that its estimate was close to the actual decommissioning cost.

Figure 10 shows that the SSJID and Tucson facilities had similar gross cost breakdowns by task. While less than half the capacity of the Tucson plant, the SSJID project was partially decommissioned at more than half the cost, resulting in 20% to 30% higher expenditures per kilowatt and about double the cost per module. Similarities and distinctions impacting costs are discussed below:

- **Demolition:** This was the highest-cost task at both the SSJID and Tucson facilities, accounting for 64% and 75%, respectively. While having a narrower scope, the SSJID project involved prevailing wage labor addressing site-specific challenges and constraints. Notably, the phased nature of redevelopment—with repeated sequencing of equipment removal then installation—delivered significant value but also introduced process inefficiencies.

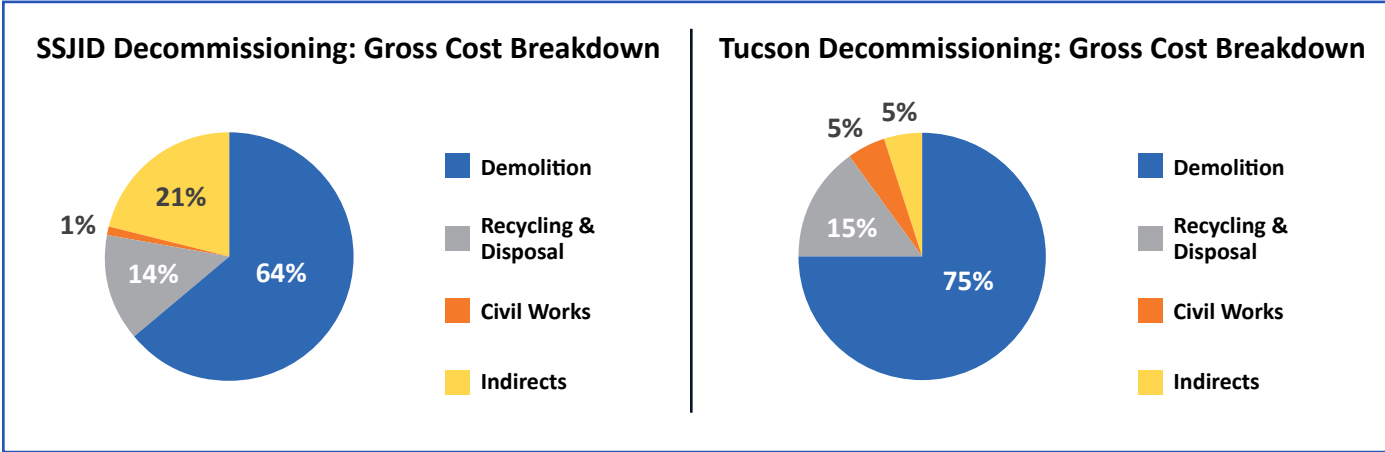


Figure 10. Real-World Decommissioning Projects: Comparison of Gross Cost Breakdowns

- Recycling and disposal:** At both projects, end-of-life CdTe modules were handled by First Solar at no additional expense, costs for offsite transportation of other recyclable materials and components were partially offset by scrap and salvage values as further discussed below, and remaining tasks amounted to about 15% of gross costs. At the SSJID facility, c-Si module transportation and recycling were the major cost drivers, with the remainder for dumpster rental and landfill tip fees. For the Tucson project, most of the cost estimate was attributed to the transportation and processing of concrete piers.
- Civil works:** Only about 1% of gross costs were required for restoration at SSJID’s redeveloped solar farm because of limited needs, as well as site characteristics. At the Tucson facility, restoration was estimated to consume 5.4% of the gross cost, with backfilling of holes left by piers expected to be the biggest contributor. Ultimately, the site owner allowed subsurface piers to be left in place, limiting actual civil work to berm restoration, backfilling, and minor grading.
- Indirects:** At 21% of gross decommissioning expenses for the SSJID project, this category included planning, engineering, and project management services provided by SSJID and NuLife, as well as construction bonding. The indirect cost fraction for the Tucson facility was

5%, covering project management and bonding but no owner’s costs. Both decommissionings involved no environmental permitting as construction activities were conducted “inside the fence” of larger facilities.

- Scrap and salvage:** At both facilities, positive cash flows were modest. SSJID received \$24,000 for used inverters and netted an additional \$26,130 primarily from recycled wires and cables; the value of materials recovered during c-Si module processing was captured by the recycler. At the Tucson facility, wires and cables, steel racking and posts, inverter cabinets, and electrical equipment generated net revenues of about \$50,000.

To support additional comparisons, Figure 11 and Table 5 (see next page) include data from the SSJID and Tucson projects and from a representative set of eight publicly available decommissioning plan cost estimates prepared in 2024-25 to enable the development of solar plants sized from 6 to 375 MW_{DC} and sited in various U.S. regions [24-31]. Planning estimates are organized by project capacity, from smallest to largest. Key factors impacting costs—both positively and negatively—are identified in the table, as previous reviews have shown that assumptions relating to work scope, module disposition, scrap and salvage value, and restoration drive the observed variability in decommissioning plan cost estimates [32].

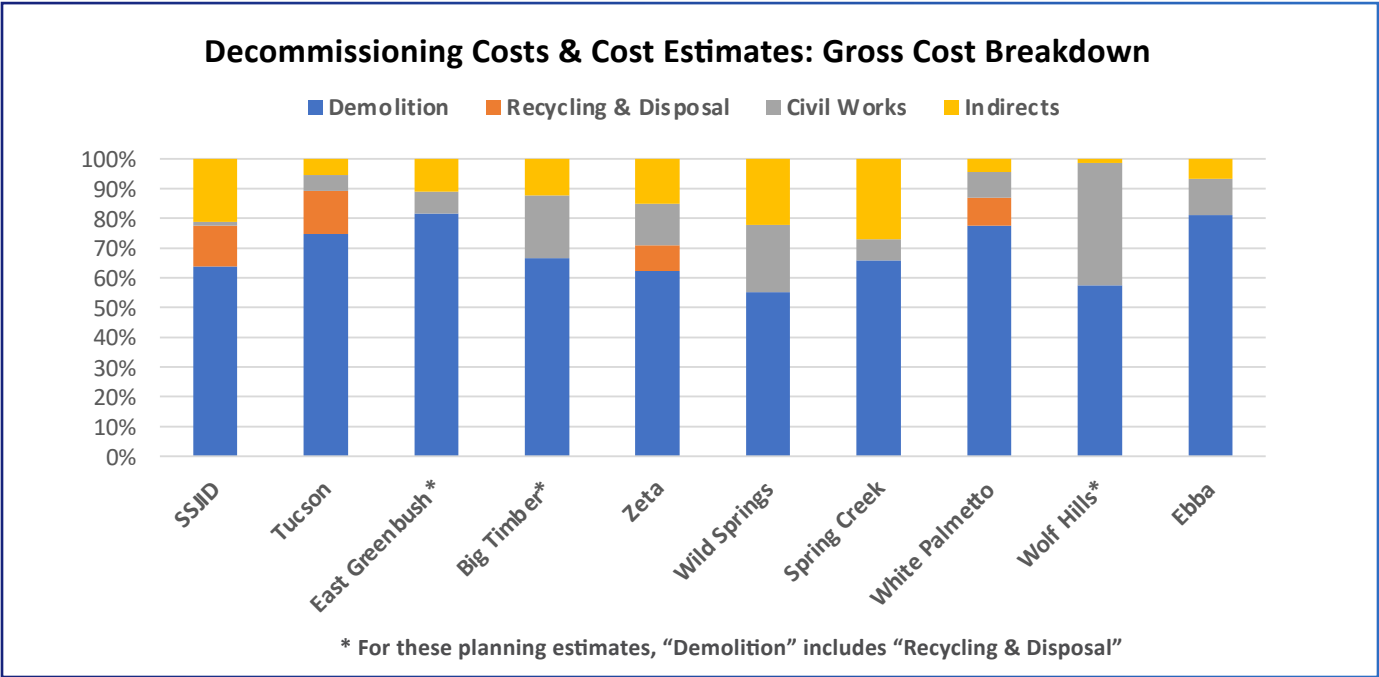


Figure 11. Decommissioning Costs and Planning Estimates: Gross Cost Breakdown

Table 5. 2024-25 Decommissioning Projects and 2024-25 Decommissioning Plan Estimates: Costs and Cost Metrics

Name	SSJID	Tucson	East Greenbush	Big Timber	Zeta	Wild Springs	Spring Creek	White Palmetto	Wolf Hills	Ebba
Cost Type (Date)	Actual (2025)	Estimate (2025)	Planning Estimate (2024)	Planning Estimate (2024)	Planning Estimate (2025)	Planning Estimate (2024)	Planning Estimate (2024)	Planning Estimate (2025)	Planning Estimate (2024)	Planning Estimate (2024)
Location	CA	AZ	NY	IL	CA	ND	MI	SC	VA	CO
Technology	CdTe, c-Si, Tracking	CdTe, Fixed	c-Si, Tracking	c-Si, Tracking	CdTe, Tracking, BESS	c-Si, Tracking	c-Si, Tracking	c-Si, Tracking	CdTe, Tracking	c-Si, Tracking, BESS
Capacity, MW _{DC}	1.5936	3.821	6*	6.25*	98.43	163	182	227.2	317.5	375*
Capacity, MW _{AC}	1.392	3	4.8	5	75	128	140	170	262	300
Number of Modules	12,480	45,000	10,902	13,700	211,680	347,580	243,658	363,468	512,136	928,044
Key Cost Drivers & Assumptions	Partial removal; CdTe module disposition cost not included; Prevailing wage labor; Indirects include owner's costs	CdTe module disposition cost not included	Scrap & Salvage not considered per state law; Restoration for future agricultural use	Modules have resale/salvage value; Restoration for future agricultural use	PV and battery modules transported and recycled at no cost	Modules have resale/salvage value	Modules have no value except for aluminum scrap; Prevailing wage labor; Indirects include owner's costs; No contouring or drainage removal included in Restoration	Modules have resale/salvage value; Subsurface removal required to 4 ft generally and 6 ft on one parcel; Indirects not included	All components have resale/salvage value; Restoration includes storm-water management pond removal	High module resale/salvage value assumed after 5 years of operation; BESS has no value
Gross Cost	\$776,256	\$1,391,120	\$166,869	\$341,662	\$4,456,117	\$15,540,885	\$36,009,274	\$19,021,000	\$18,226,196	\$15,540,344
Gross \$/kW	\$487/kW _{DC} \$558/kW _{AC}	\$364/kW _{DC} \$464/kW _{AC}	\$28/kW _{DC} \$35/kW _{AC}	\$55/kW _{DC} \$68/kW _{AC}	\$45/kW _{DC} \$59/kW _{AC}	\$95/kW _{DC} \$121/kW _{AC}	\$198/kW _{DC} \$257/kW _{AC}	\$84/kW _{DC} \$112/kW _{AC}	\$57/kW _{DC} \$70/kW _{AC}	\$41/kW _{DC} \$52/kW _{AC}
Gross \$/Module	\$62	\$31	\$15	\$25	\$21	\$45	\$148	\$52	\$35	\$17
Scrap & Salvage	-\$50,130	-\$50,000	Not applicable	-\$125,396	-\$1,695,700	-\$11,398,284	-\$1,044,224	-\$12,890,000	-\$19,339,684	-\$59,600,660
Net Cost	\$726,126	\$1,341,120	\$166,869	\$216,266	\$2,760,417	\$4,142,601	\$34,965,050	\$6,131,000	-\$1,113,488	-\$44,060,316
Net \$/kW	\$456/kW _{DC} \$522/kW _{AC}	\$351/kW _{DC} \$447/kW _{AC}	\$28/kW _{DC} \$35/kW _{AC}	\$35/kW _{DC} \$43/kW _{AC}	\$28/kW _{DC} \$37/kW _{AC}	\$25/kW _{DC} \$32/kW _{AC}	\$192/kW _{DC} \$250/kW _{AC}	\$27/kW _{DC} \$36/kW _{AC}	-\$3/kW _{DC} -\$4/kW _{AC}	-\$117/kW _{DC} -\$147/kW _{AC}
Net \$/Module	\$58	\$30	\$15	\$16	\$13	\$12	\$144	\$17	-\$2	-\$47

*DC capacity is calculated based on an assumed inverter loading ratio of 1.25.

Across the planning estimates, gross costs range from about \$167,000 to \$36 million, but consistent economies of scale are not evident. Demolition accounts for the largest share of gross costs for the actual decommissionings and planning estimates. SSJID has the third-highest indirects share, exceeded by two planning estimates, Wild Springs and Spring Creek, that include 15% contingencies, with the latter also incorporating owner's costs. SSJID and Tucson show the lowest civil works shares, while five of eight planning estimates allocate more than 12% for site restoration. At Wolf Hills, the high of 41% for civil works is driven by removal of stormwater retention ponds. SSJID and Tucson have the highest recycling and disposal shares despite not requiring any expenditures for CdTe module transportation and processing. Only two planning estimates include recycling and disposal costs as a line item; the others treat these expenses as demolition costs or report only scrap and salvage revenues.

For the SSJID and Tucson projects, gross \$/kW costs are at least double and as much as 15 times higher than the planning estimates, which range from about \$30 to above \$200 per kW. By contrast, gross \$/module costs for SSJID and Tucson are within or slightly higher than the \$15 to \$52 range spanning seven of the eight planning estimates, with the outlier, Spring Creek, at \$148/module driven by prevailing wage labor. Broadly, elevated \$/kW values appear consistent with the smaller size of the SSJID and Tucson facilities, while comparable \$/module costs align with the lower wattage of legacy modules.

Scrap and salvage credits, shown in red in Table 5, have minimal impacts on these metrics for the SSJID and Tucson decommissionings, with net costs only about 6.5% and 3.6% lower, respectively. One planning estimate, Spring Creek, also shows a minimal (2.9%) reduction as modules are valued only for recovery of aluminum frames; another, East Greenbush, does not account for scrap and salvage value based on state law. For four others—Big Timber, Zeta, Wild Springs, and White Palmetto—net costs are in the range of 36% to 74% lower, translating into similar reductions in net \$/kW and \$/module metrics. The remaining two planning estimates, Wolf Creek and Ebba, incorporate scrap and salvage values that exceed gross costs, resulting in negative net costs and metrics. Planning estimates indicating low net decommissioning costs or positive cash flows can assist



Figure 12. Reusing underground conduit (top) to supply string inverters and other equipment deployed on the existing concrete pad (middle) were key elements to successful redevelopment (bottom). (Credit: NuLife Power Services)

project developers and asset owners in delaying the onset and magnitude of decommissioning surety requirements.

COST MODELING TOOL CALIBRATION [33]

As described in Box 1 (see page 19), the PV RESOLVE cost modeling tool is designed to serve as a standardized and transparent framework for estimating the cost of utility-scale PV decommissioning and repowering projects. The

tool draws on 2025 cost estimates prepared for nine conceptual solar plant designs representing common variations in PV system configuration. These bottom-up estimates—based on quantity, time, and material estimates specific to each permutation—were developed by an engineering, procurement, and construction contractor using Association for the Advancement of Cost Engineering (AACE) Class 4 standards (expected accuracy range of -20% to +30%) [34].

Figure 13 displays these cost estimates, showing gross (total) cost ranges of \$255-\$264/kW_{AC} for two 20-MW_{AC} cases and \$145-\$194/kW_{AC} for seven 200-MW_{AC} configurations. Smaller plants show the effects of limited economies of scale in labor and equipment mobilization. Lower inverter loading reduces costs due to fewer modules and less DC-side equipment and materials for a given AC capacity. Removal of fixed-tilt arrays requires less labor, materials, and heavy machinery. Plants dispersed over multiple parcels and located in hilly terrain increase complexity, labor, and equipment mobilization requirements.

For myriad reasons discussed above, actual \$/kW_{AC} costs for partial decommissioning of SSJID’s solar farm were about 2 to 4 times higher than the cost estimates used in developing the PV RESOLVE modeling tool. Applying case study data for modeling tool calibration was limited by proj-

ect scope and by site-specific and scale-dependent factors. Most significantly, observed direct labor costs for module and inverter removal were about 70% higher than modeled values, likely influenced by the phased nature of the repowering and additional time and precautions involved in working around operational tracking arrays, detaching spot-welded c-Si modules, and protecting components and systems designated for reuse. Some task-level line items within the modeling tool were updated to allow for additional user-defined adjustments, including for legacy solar plants where fixed expenses are allocated across a lower amount of capacity.

CONCLUSIONS

SSJID’s partial decommissioning and redevelopment of the Robert O. Schulz Solar Farm delivered immediate benefits by substantially increasing solar energy production and annual energy cost savings without expanding the project’s physical footprint. Engineering-level field assessments directly shaped decisions regarding equipment reuse and replacement and redevelopment sequencing and phasing, helping ensure that the repowering was completed on schedule, within the originally authorized budget, and without significant production losses.

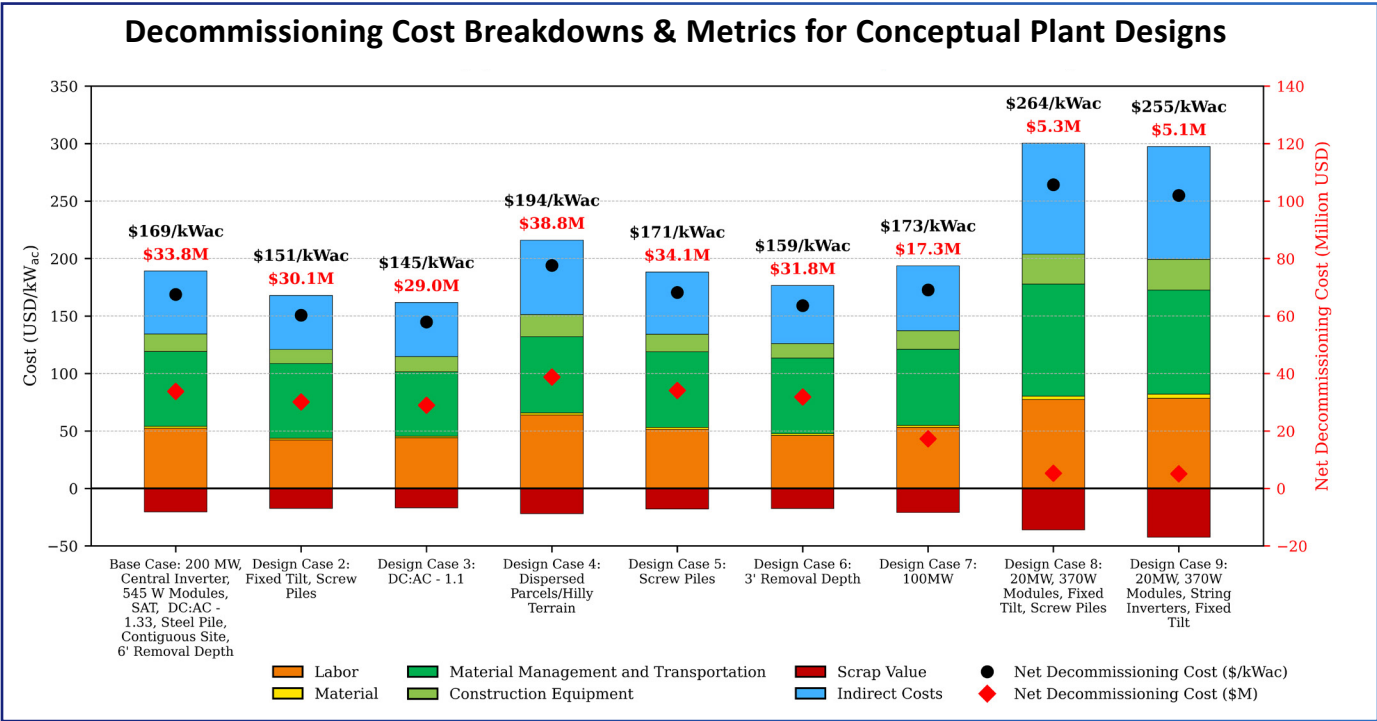


Figure 13. Decommissioning Estimates for Conceptual Plant Designs Used in PV RESOLVE Cost Modeling Tool Development

BOX 1: PV RESOLVE DECOMMISSIONING AND REPOWERING COST MODELING TOOL OVERVIEW [35]

Scheduled to be available for public use by Fall 2026, the PV RESOLVE modeling tool is designed to assist owners and operators of utility-scale ground-mount solar plants—as well as other stakeholders—in estimating decommissioning and repowering costs, evaluating asset retirement obligations, and assessing mid-life intervention strategies.

The tool requires users to specify project type—complete decommissioning, revamping, or redevelopment—and to input baseline information including module and plant capacity rating, inverter architecture and loading ratio, racking and foundation type, site layout, and removal depth for underground systems. Users can specify additional design parameters and adjust default economic assumptions regarding labor rates, hauling distances and rates, disposal and recycling fees, commodity prices for recoverable materials, and equipment procurement and installation costs for repowering projects.

Based on user inputs, the tool develops cost estimates by applying a comprehensive task library of 167 line items encompassing the full scope of required decommissioning activities, first-order scaling factors derived by analyzing conceptual design permutations, and systematic deviations attributable to secondary drivers. For example, inverter removal costs for a given facility are contingent primarily on inverter count and secondarily on type, and they are estimated based on task-specific labor hours and rates, equipment hours and productivity assumptions, and corresponding

equipment rental or ownership-and-operation costs. Task-level results are aggregated to system-level subtotals and gross (total) direct costs. Indirect costs are applied as user-defined adders to produce overall estimates consistent with standard construction cost accounting conventions.

The tool's primary output is total net project cost for decommissioning or repowering, in constant December 2024 U.S. dollars. Results are also disaggregated by system area (solar array and substation) and by cost component (labor, material (consumables), construction equipment, material management and transportation, scrap value, and indirects). Normalized metrics are reported as $\$/kW_{AC}$ and $\$/module$, enabling comparison across plant sizes, configurations, and revamping and redevelopment scenarios.

PV asset owners and operators can evaluate mid-life, reinvestment, and retirement pathways and use the tool to inform decommissioning planning for both existing and new PV facilities. Lenders, insurers, and investors can apply the tool during due diligence to reduce uncertainty, avoid overly conservative or aggressive assumptions, and enable portfolio-level comparisons. Independent engineers can use the industry-vetted framework to assess decommissioning and repowering scenarios across plant designs and locations, supporting consistent reporting to owners, financiers, and regulators. Policymakers can reference the results to inform permitting, financial assurance, and evidence-based regulatory reviews.

The flexible, shared-risk approach to contracting also avoided scope expansions that would have been standard practice for a conventional engineering, procurement, and construction arrangement. Simple payback is expected in less than 2 years (within 3 years not counting IRA incentives), and the repowered facility is projected to deliver at least \$1.5 million in annual value for the foreseeable future—pending changes to utility tariffs and NEM provisions—and to continue operating beyond 2040.

The unique attributes of the SSJID facility and its redevelopment create challenges in applying case study cost data to inform site-specific decommissioning and repowering planning or to support calibration of the decommissioning and repowering cost modeling tool developed for utility-scale solar power plants through the PV RESOLVE project. However, owners of other legacy or underperforming solar plants can learn from case study experiences in evaluating asset management options, assessing repowering opportunities

and constraints, and developing and implementing creative equipment reuse and replacement strategies and phased redevelopment plans.

For mid-life solar assets, continuous monitoring and professional O&M are essential to prevent compounding performance and reliability issues. While legacy arrays pose repowering challenges, opportunities exist to significantly extend lifetime and increase capacity within the same footprint. Decisions on whether to retain or replace components involve tradeoffs among costs and risks and across procurement, labor, and other cost centers. Repowering contractors capable of field engineering decisions and project structures offering flexibility and risk-sharing can add significant value, especially for projects lacking as-built drawings and O&M records. Careful phasing and sequencing of redevelopment tasks can help reduce downtime, production losses, and cost impacts.

ACKNOWLEDGMENTS

This PV RESOLVE project case study report was developed based upon funding from the Alliance for Energy Innovation, LLC, the Managing and Operating Contractor for the National Laboratory of the Rockies for the U.S. Department of Energy. The contributions of the following individuals are greatly appreciated: Bill Schwandt, South San Joaquin Irrigation District; Cesar Barbosa, NuLife Power Services; and Jerry Darco, Decom Solar.

REFERENCES

1. EPRI (2023). *Repowering Utility-Scale Solar Power Plants: Planning Recommendations and Best Practices*. [3002018665](#)
2. EPRI (2020). *Decommissioning Plans for Large-Scale Solar Plants: Issues, Uncertainties, and Opportunities*. [3002019089](#)
3. Haavind, B. (2009). "Solar shootout in the San Joaquin Valley," *Renewable Energy World*, May 1; <https://www.renewableenergyworld.com/solar/solar-shootout-in/>
4. Shields, J. (2009). "Side by Side: Thin Film vs. Crystalline PV Array." Presented to Virtual Energy Forum, June 24-25, 2009.
5. Haavind, 2009
6. SSJID (2022-23). "Monthly Staff Reports to Board of Directors."
7. SSJID, 2022-23
8. Terraverde Energy (2021a). "SSJID Operational Assessment."
9. Deline, C., Perry, K., Springer, M., Jordan, D., Muller, M., White, R., Ovatt, S., and Meyers, B. (2026). "PV Fleet Performance Data Initiative - 2026 update." *Proceedings of the 2026 PV Reliability Workshop*, Lakewood, Colorado, February 2, 2026.
10. Terraverde Energy (2021b). "Quarterly Asset Management Report, Q3 2021, South San Joaquin Irrigation District."
11. SSJID (2023-24). "Monthly Staff Reports to Board of Directors."
12. SSJID (2023). "Request for Proposal for Renewable Energy Engineering Services: Repowering an Existing 1.6 Megawatt Solar Farm."
13. SSJID, 2023-24
14. Jolt Engineering (2024). "New PV System: 810.00 kW DC/660.00 kW AC, SSJID 660 KW PV2 Solar Farm Repower."
15. SSJID (2024-25). "Monthly Staff Reports to Board of Directors."
16. Jolt Engineering (2025a). "New PV System: 648.00 kW DC/500.00 kW AC, SSJID PV1-A Solar Farm Repower."
17. Jolt Engineering (2025b). "New PV System: 864.00 kW DC/667.00 kW AC, SSJID PV1-B Solar Farm Repower."
18. California Department of Toxic Substances Control (2025). "Photovoltaic (PV) Modules (Including Solar Panels) Universal Waste Management – Frequently Asked Questions"; <https://dtsc.ca.gov/solar-panel-faqs/>
19. First Solar (2025). "Technology: Uniquely American"; <https://www.firstsolar.com/Technology/Manufacturing>
20. PedalPoint (2026). "Solar Panel Recycling"; <https://pedalpoint.co/pedalpoint-solar-recycling/>
21. SSJID (2025-26). "Monthly Staff Reports to Board of Directors."
22. EPRI (2025). "PV Module Recycler Survey" (unpublished).
23. Feldman, D., Zuboy, J., Dummit, K., Stright, D., Heine, M., Grossman, S., and Margolis, R. (2024). *Spring 2024 Solar Industry Update*. NREL/PR-7A40-90042; <https://docs.nrel.gov/docs/fy24osti/90042.pdf>
24. Black & Veatch, Inc. (2024). *Decommissioning Cost Estimate and Basis, Spring Creek Solar, Barry County*. Prepared for Consumers Energy, August 29, 2024.

25. Citrine Power LLC (2024). *New York Community Solar Facility Decommissioning Plan & Procedure Agreement*. Prepared for Town of East Greenbush, December 10, 2024.
26. GZA Geoenvironmental, Inc. (2025). *Proposed Zeta Solar and Battery Energy Storage System Facility: Decommissioning and Reclamation Plan*. Prepared for Longroad Energy LLC, February 7, 2025.
27. HDR Engineering, Inc. (2025). *Decommissioning Plan for White Palmetto Solar Energy System*. Prepared for TOCE Solar 1 LLC, April 22, 2025.
28. Kimley-Horn & Associates, Inc. (2024a). *Decommissioning Plan, Big Timber Solar Farm LLC*. Prepared for Surya Powered LLC, September 9, 2024.
29. Kimley-Horn & Associates, Inc. (2024b). *Ebba Solar Decommissioning Plan*. Prepared April 2024.
30. Timmons Group (2024). *Wolf Hills Solar Decommissioning Plan*. Prepared for Catalyst Energy, May 29, 2024.
31. Westwood Professional Services, Inc. (2024). *Estimated Decommissioning Costs, Wild Springs Solar Project*. Prepared March 7, 2024.
32. EPRI, 2020 and 2023
33. Kumar, A., Libby, C., Bedilion, R., *et al.* (in press). "Development and Application of a Decommissioning and Repowering Cost Modeling Tool for Utility-Scale Solar PV Power Plants."
34. EPRI (2025). *PV Plant Decommissioning and Repowering: Cost and Materials Estimates for Conceptual Plant Designs*, [3002032439](#)
35. Kumar *et al.*, in press

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

THIS DOCUMENT WAS PREPARED BY THE ORGANIZATION(S) NAMED BELOW AS AN ACCOUNT OF WORK SPONSORED OR COSPONSORED BY THE ELECTRIC POWER RESEARCH INSTITUTE, INC. (EPRI). NEITHER EPRI, ANY MEMBER OF EPRI, ANY COSPONSOR, THE ORGANIZATION(S) BELOW, NOR ANY PERSON ACTING ON BEHALF OF ANY OF THEM:

(A) MAKES ANY WARRANTY OR REPRESENTATION WHATSOEVER, EXPRESS OR IMPLIED, (I) WITH RESPECT TO THE USE OF ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, OR (II) THAT SUCH USE DOES NOT INFRINGE ON OR INTERFERE WITH PRIVATELY OWNED RIGHTS, INCLUDING ANY PARTY'S INTELLECTUAL PROPERTY, OR (III) THAT THIS DOCUMENT IS SUITABLE TO ANY PARTICULAR USER'S CIRCUMSTANCE; OR

(B) ASSUMES RESPONSIBILITY FOR ANY DAMAGES OR OTHER LIABILITY WHATSOEVER (INCLUDING ANY CONSEQUENTIAL DAMAGES, EVEN IF EPRI OR ANY EPRI REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES) RESULTING FROM YOUR SELECTION OR USE OF THIS DOCUMENT OR ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT.

REFERENCE HEREIN TO ANY SPECIFIC COMMERCIAL PRODUCT, PROCESS, OR SERVICE BY ITS TRADE NAME, TRADEMARK, MANUFACTURER, OR OTHERWISE, DOES NOT NECESSARILY CONSTITUTE OR IMPLY ITS ENDORSEMENT, RECOMMENDATION, OR FAVORING BY EPRI.

THE FOLLOWING ORGANIZATION, UNDER CONTRACT TO EPRI, PREPARED THIS REPORT:

Water Energy Ecology Information & Design Services, Inc.

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, and affordable access to electricity across the globe. Together...Shaping the Future of Energy®

AI Use

Your use of this product with AI tools will follow the internal business use terms of the respective agreement between your company and EPRI. You understand that some AI tools do not protect intellectual property and can produce inaccurate or biased results. Furthermore, you understand that use of this product with AI tools in an unauthorized manner may trigger contractual remedies and/or lead to significant consequences.

EPRI CONTACT

CARA LIBBY, *Technical Executive,
Renewable Energy*
650.776.6009, clibby@epri.com

For more information, contact:

EPRI Customer Assistance Center
800.313.3774 • askepri@epri.com



3002034859

May 2026

EPRI

3420 Hillview Avenue, Palo Alto, California 94304-1338 USA • 650.855.2121 • www.epri.com

© 2026 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ENERGY are registered marks of the Electric Power Research Institute, Inc. in the U.S. and worldwide.